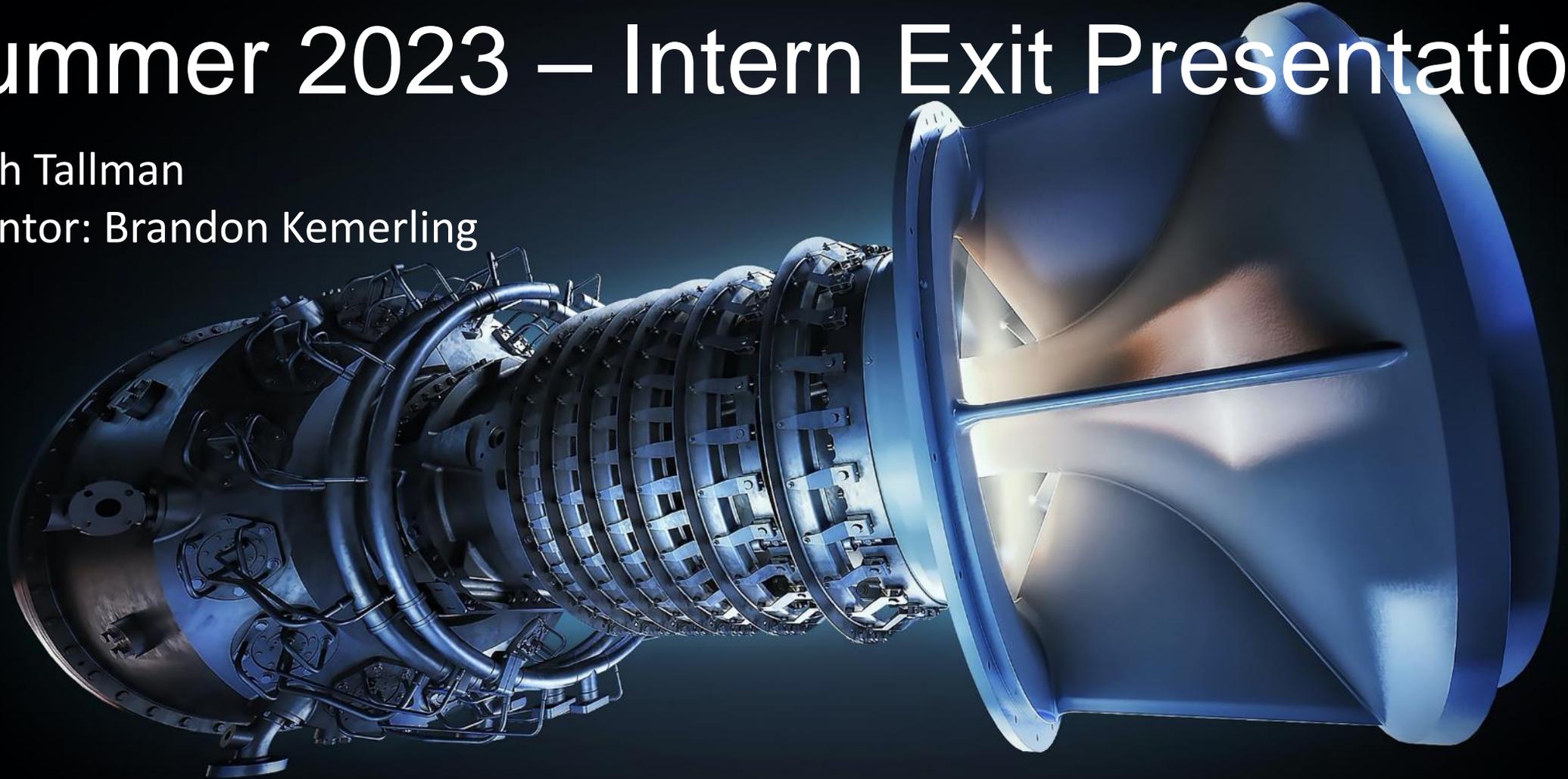


Additive Manufacturing Design

Summer 2023 – Intern Exit Presentation

Zach Tallman

Mentor: Brandon Kemerling

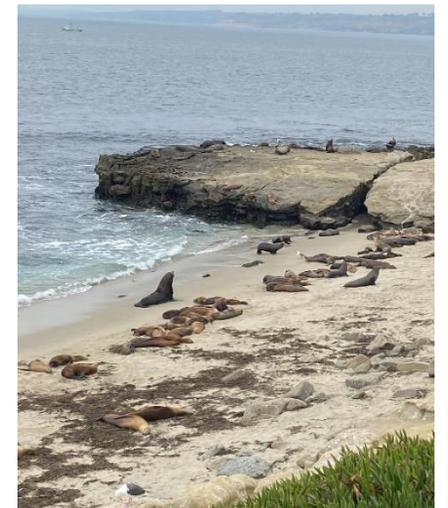


Solar Turbines
A Caterpillar Company

Powering the Future

Background/Intro

- Born/raised in Morgantown, WV
- B.S. in Aerospace & Mechanical Engineering, minor in Math from WVU
- Working on M.S. in Aerospace Engineering, also from WVU
Thesis on heat flux sensor for RDEs
- Love animals, travelling, food
- Hobbies
 - Dungeons & Dragons
 - Video games
 - Drawing/modelling
 - Cooking
 - 3D Printing



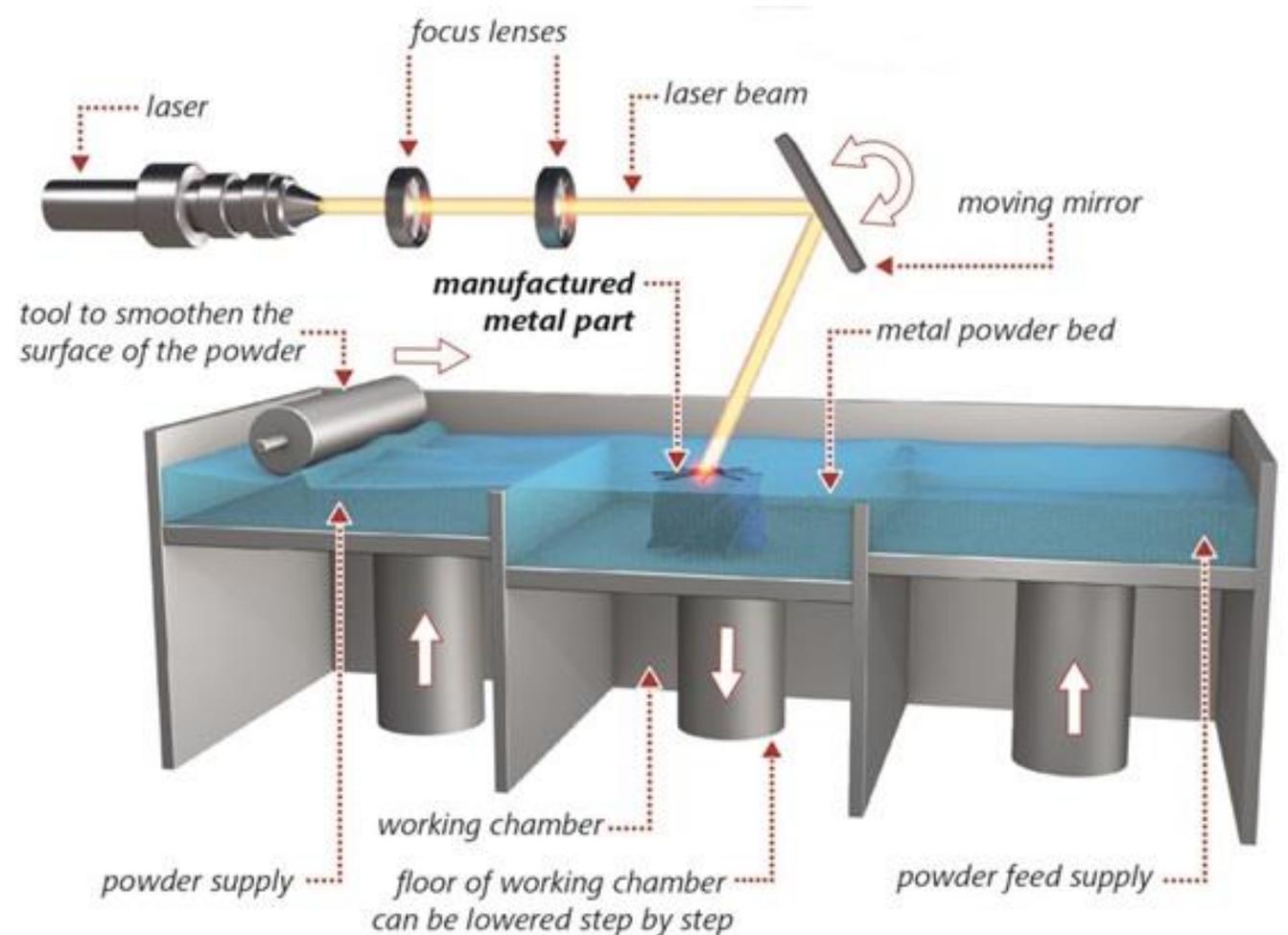
Agenda

- 3D Printing Process
- Project #1: Cooling Insert Re-design
- Project #2: MET Roughness Characterization
- Acknowledgements



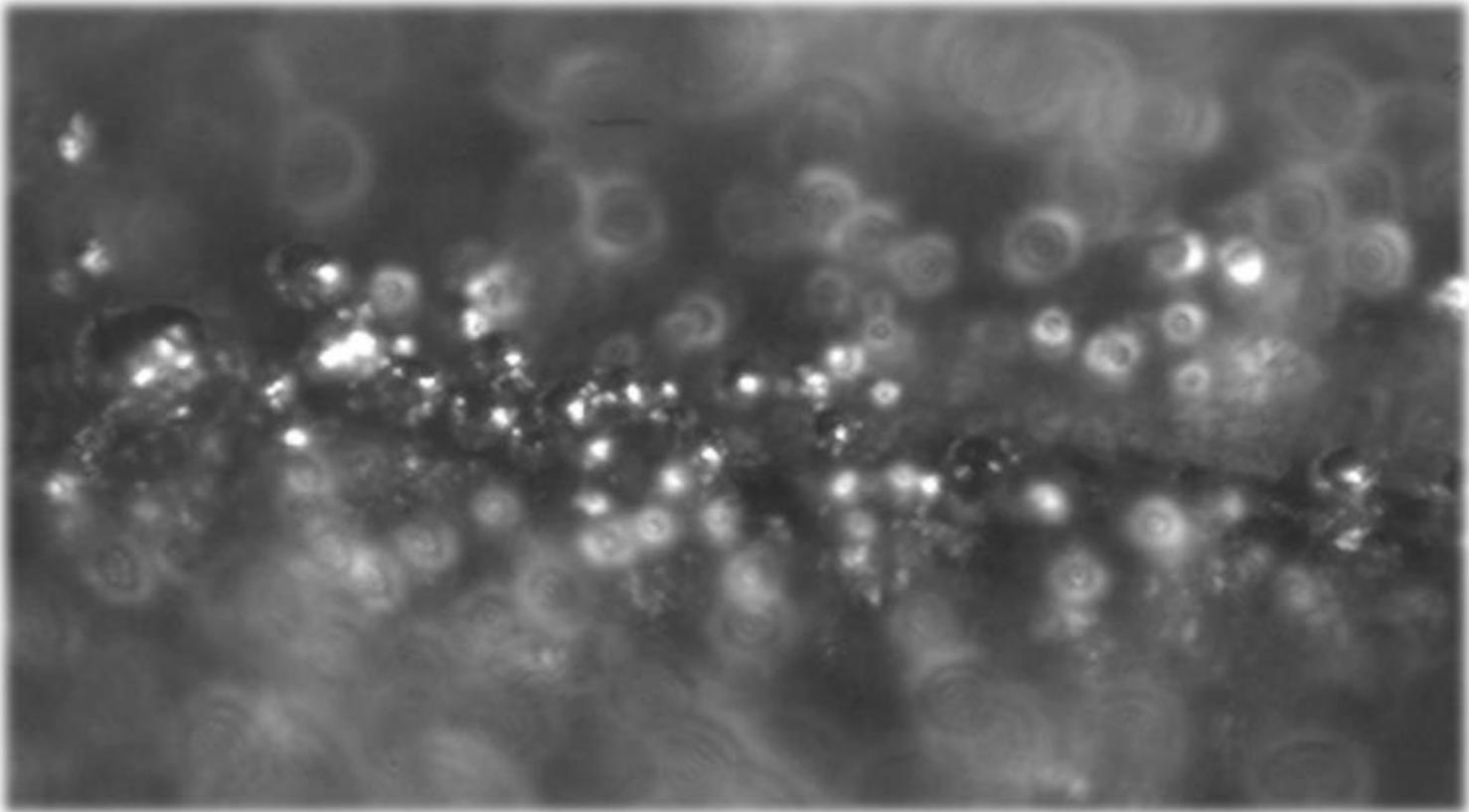
3D Printing Process

- 3D printing – building a part from the ground up
- Current printers separate parts into layers, adding material at each layer
- Advantages
 - Able to build complex geometry difficult or impossible to replicate with traditional manufacturing
 - Rapid prototyping
 - Part consolidation
 - Time & cost reduction

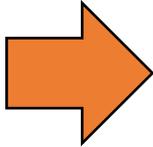


Source: Leinenbach, Christian. "Selective Laser Melting." *Empa: Materials Science and Technology*, www.empa.ch/web/coating-competence-center/selective-laser-melting.

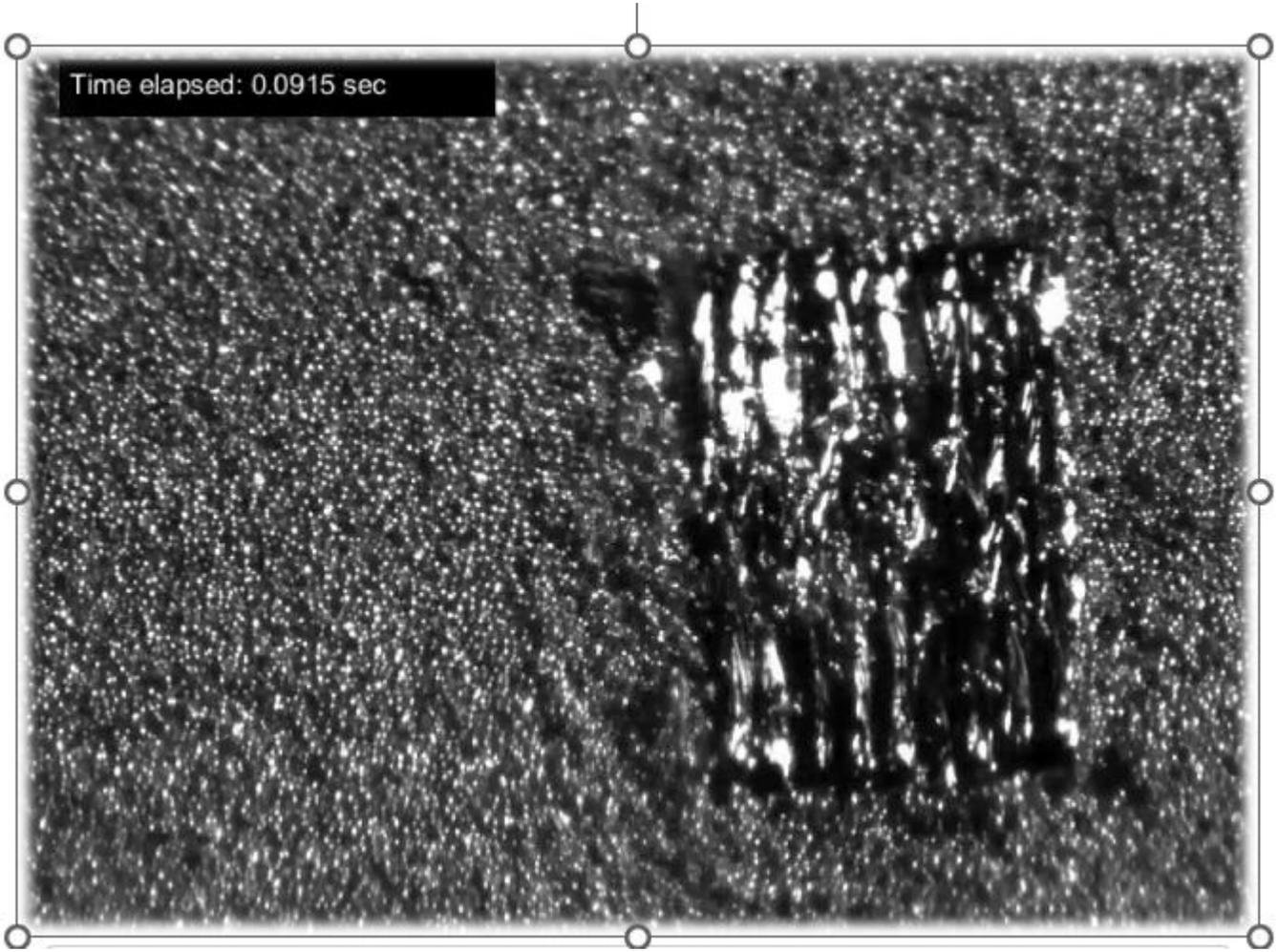
Laser-Powder Bed Fusion



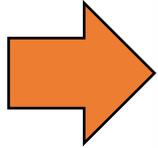
Metal Powder + Micro Laser Weld



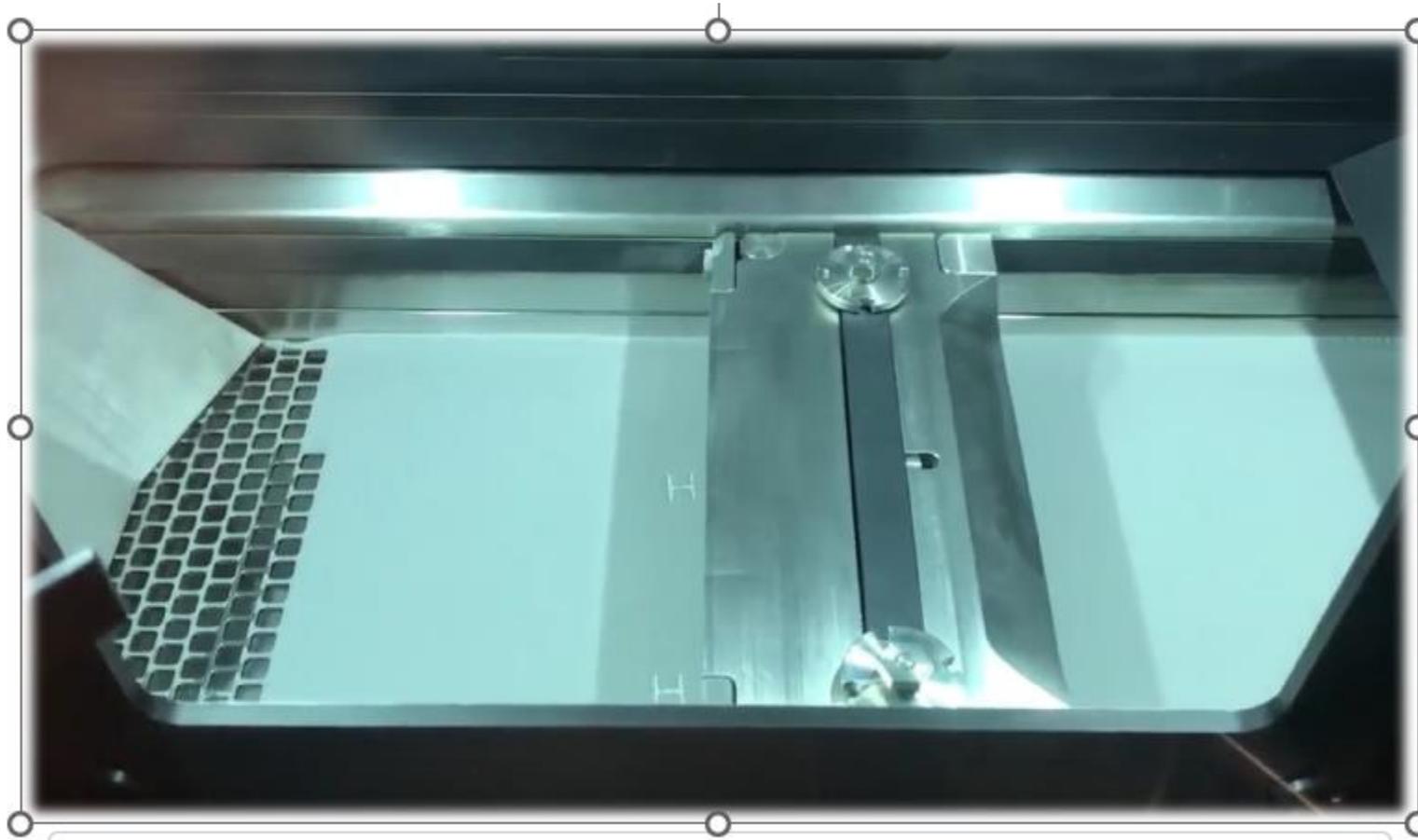
Laser-Powder Bed Fusion



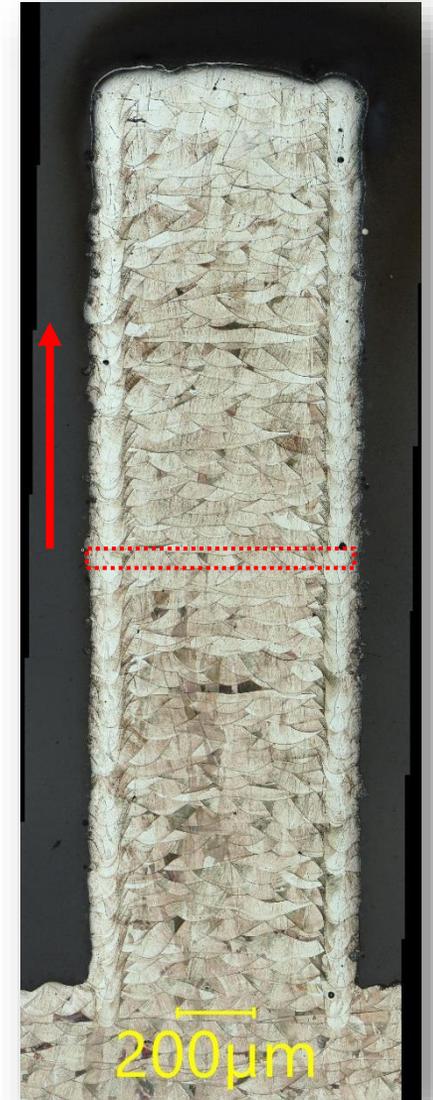
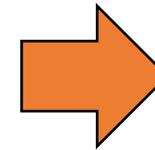
Overlapping micro welds (0.004" wide)



Laser-Powder Bed Fusion



Selective melting of 1 layer... repeat.



Project #1

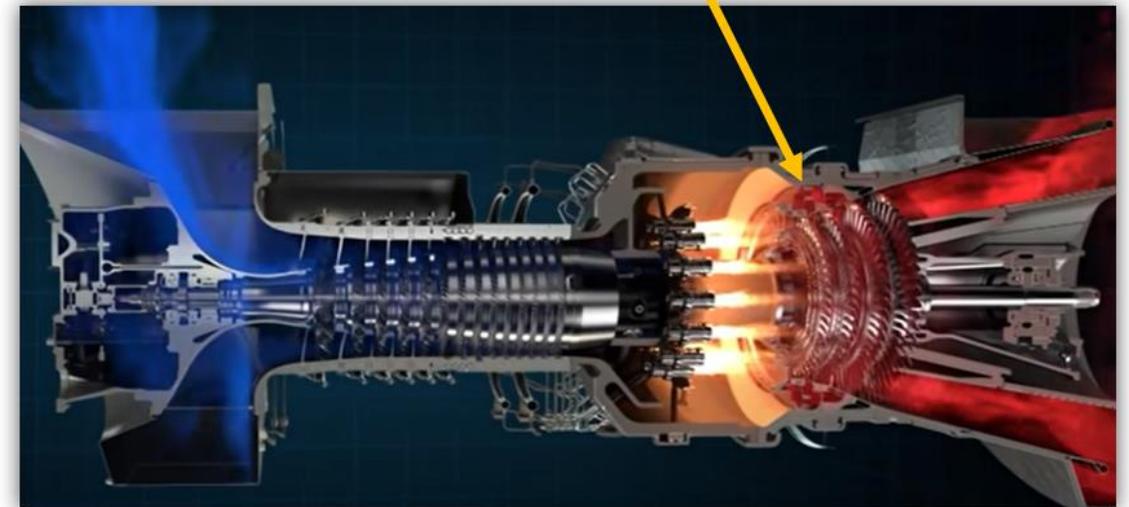
Cooling Insert Design Review

Project #1: Purpose

- Goal: Investigate viability and benefits of an AM transition for cooling insert production
 - Leverage L-PBF technology to improve existing designs with features unavailable to traditional manufacturing
 - Determine savings per part (production time and cost)
- Motivations for AM transition
 - Resilience to supply chain upsets
 - Assembly time reduction
 - Competitive cost
 - Design flexibility
 - Changes to design require little to no changes in manufacturing process
 - More design freedom

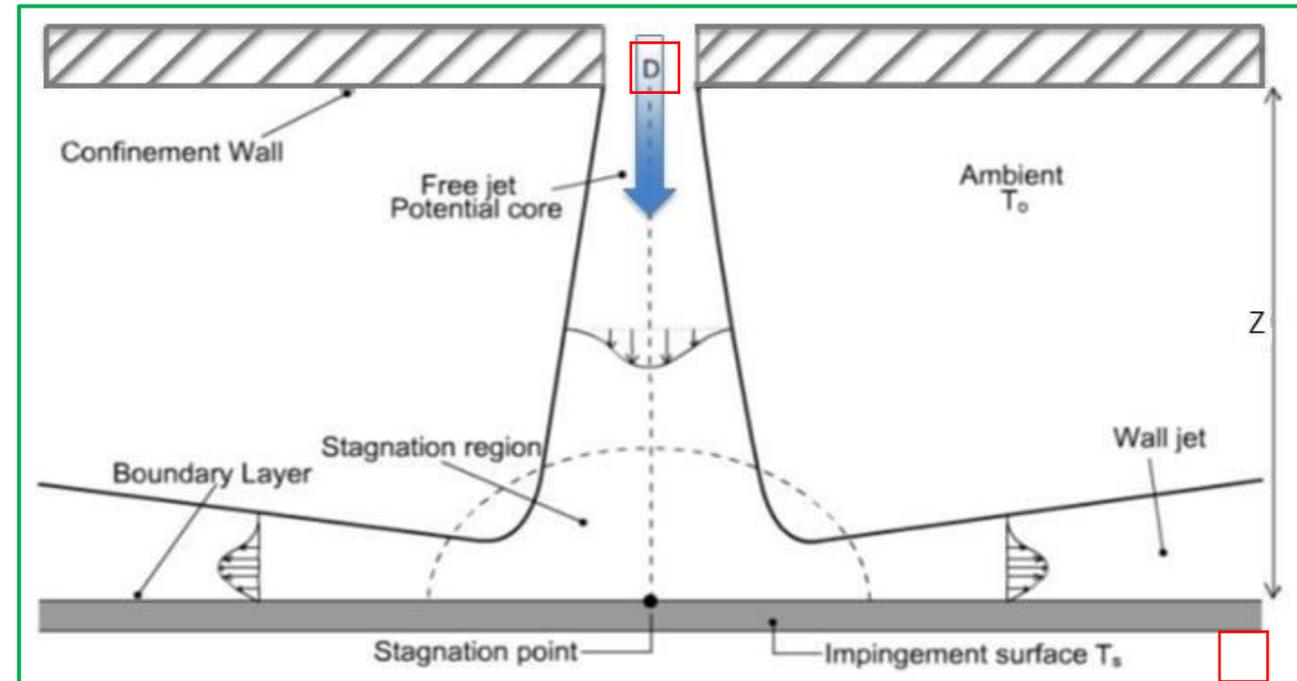


Location of Cooling Inserts



Project #1: Methodology

- Added features aimed to improve cooling
- Two primary parameters of concern
 1. Jet-to-wall distance (Z/D)
 - Cooling increases the closer the hole is to heated surface
 - Less time for heat exchange with ambient (hot) air
 2. Hole length (L/D)
 - Longer holes improve cooling
 - Allow more time for flow to develop before exiting
 - More uniform velocity profile at jet initiation



Project #1: Results

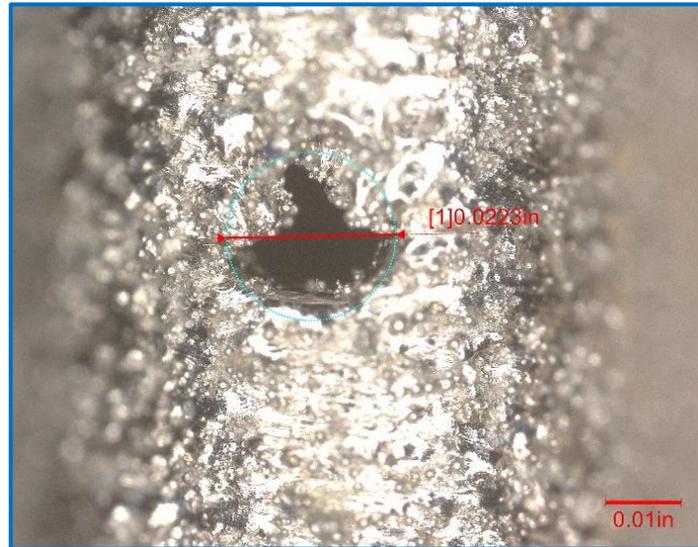
Finished Parts



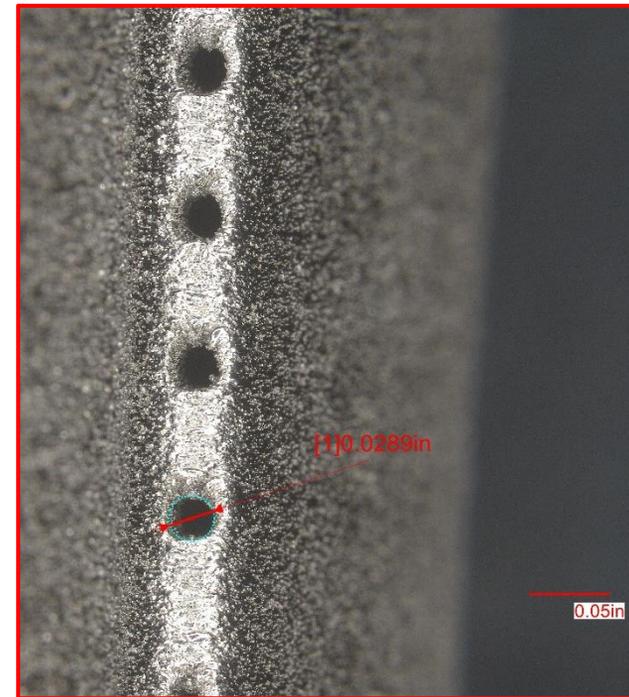
Project #1: Results

AM Hole Shape

Non-Optimized



Optimized

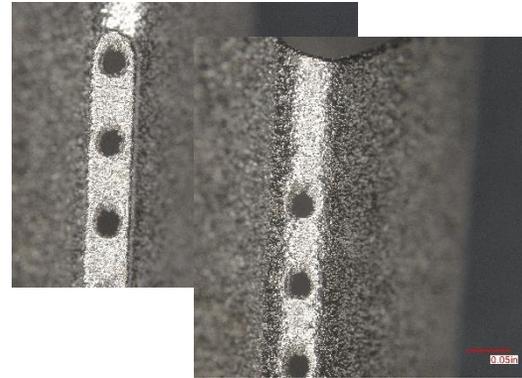


Project #1: Related Projects



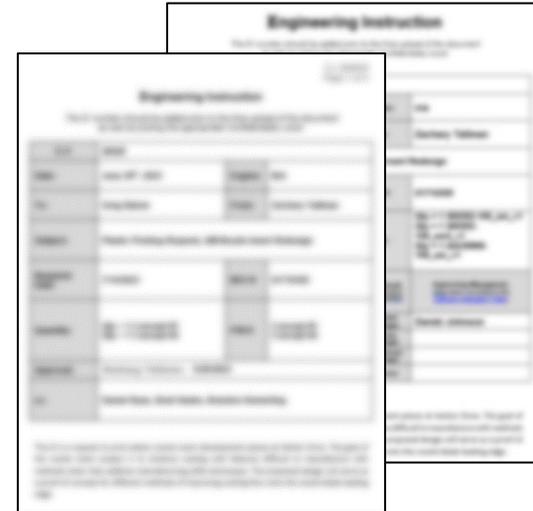
Insert Plastic Prints

- First printed design models in plastic
- Prepared Creo models for FDM and SLA
- Sliced file and prepared for printing



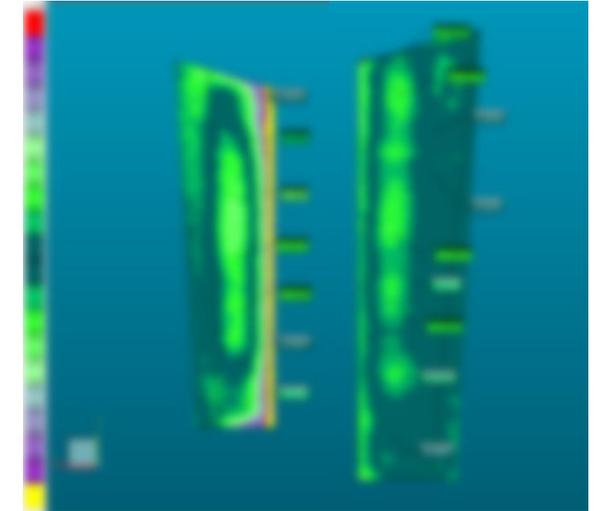
Micro Imaging

- Used microscope to capture hole images
- Captured hole images for each set of holes on each insert
- Compared to production insert holes



Engineering Instruction (EI) Creation

- Submitted two EI's during internship
- Plastic print request
- Metal print request



3D Scans

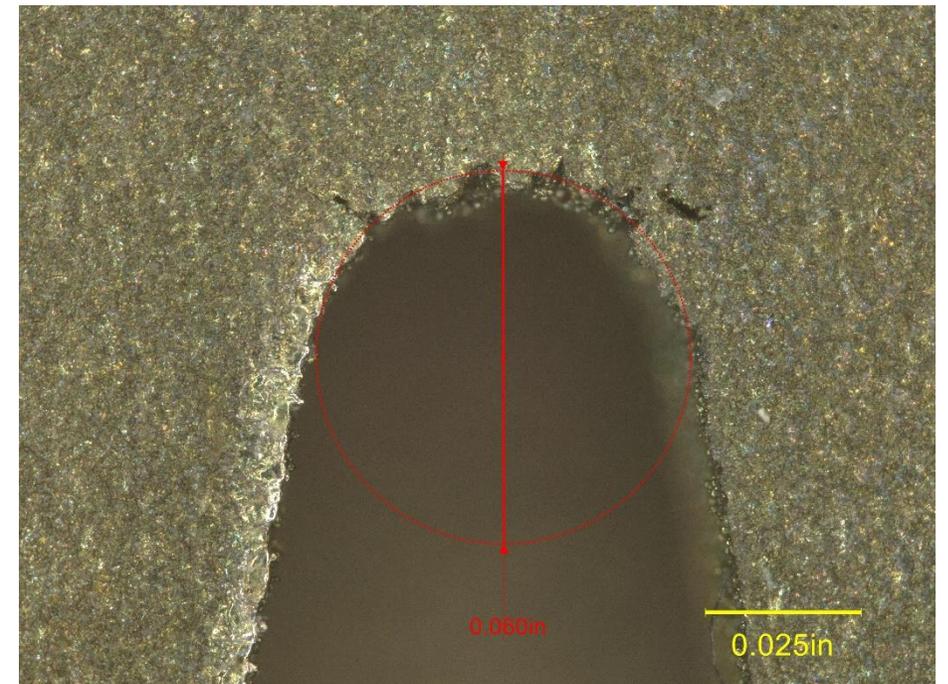
- Scanned cooling insert
- Scans used to compare model with printed part
- Useful in tolerancing and print quality

Project #2

MET Surface Roughness Application Development

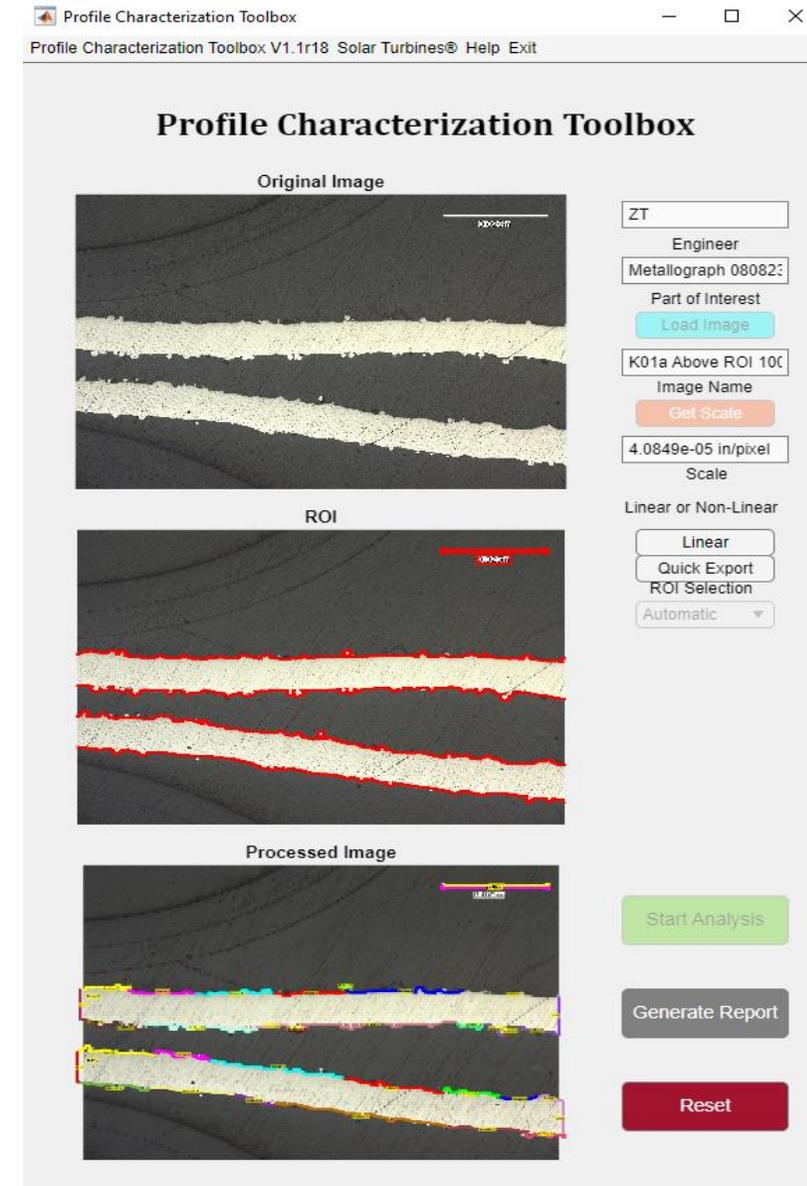
Project #2: Purpose

- Goal: Tune MATLAB app to improve robustness and troubleshoot errors
 - App characterizes surface roughness using a cross-section image
 - Traces boundary & calculates parameters along length
- Motivations
 - Surface roughness is a major concern with AM parts
 - Surface finish tolerances must be met
 - Down-skin faces and overhangs
 - Important to characterize surface stress concentrations or features that may interrupt flow
 - Development of compensation strategies



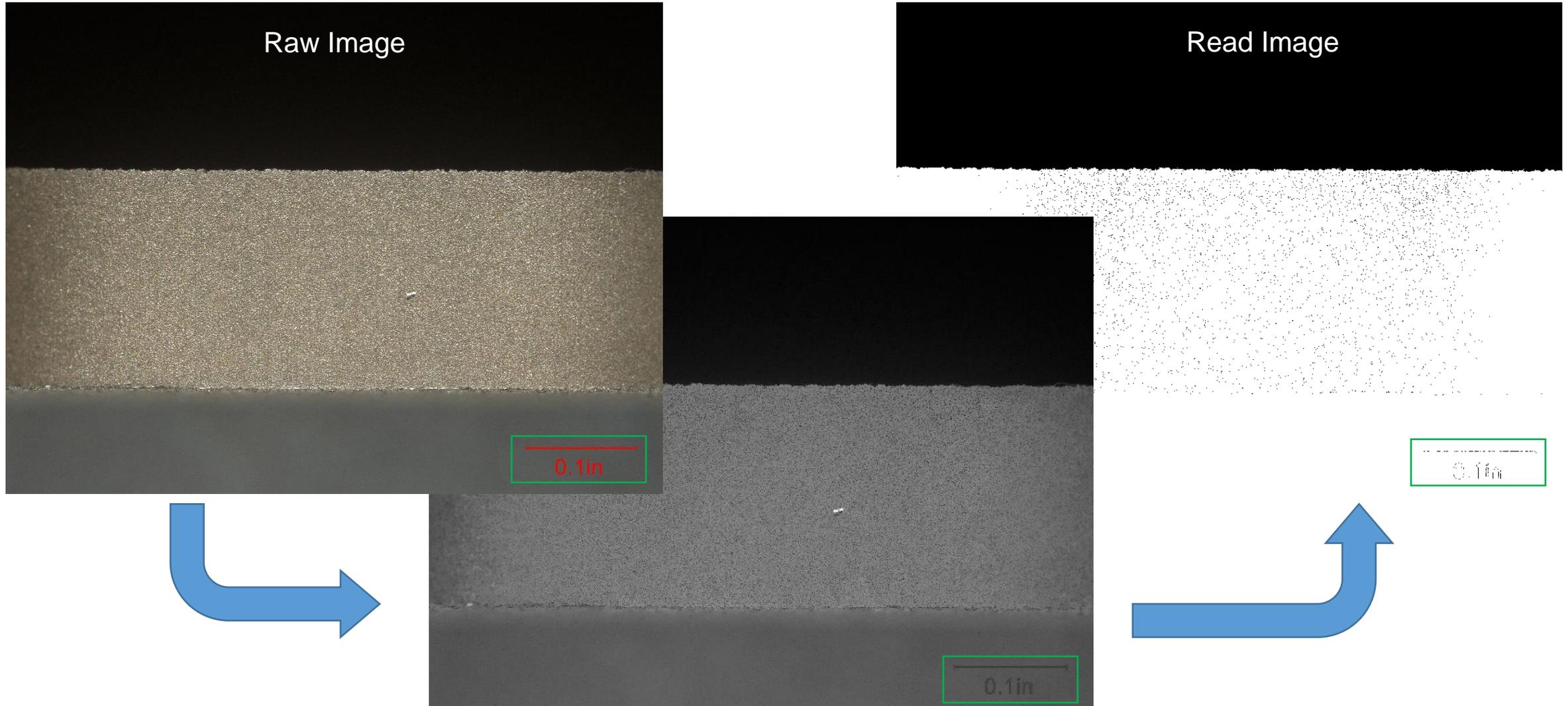
Project #2: Background

- Development began prior to internship
- Captures scale and traces section outline
 - Uses text recognition AI to read scale value
 - Linear or non-linear profiles
 - Able to designate a custom region of interest (ROI)
- Several roughness parameters are calculated in the application
 - Roughness average (R_a)
 - Total height of profile (R_t)
 - Local maximum height (R_z)
- **Current challenges**
 - Scale capture reliability
 - Analysis accuracy
 - Application validation
 - Report generation

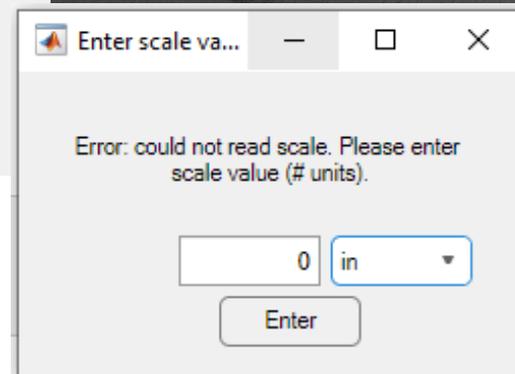
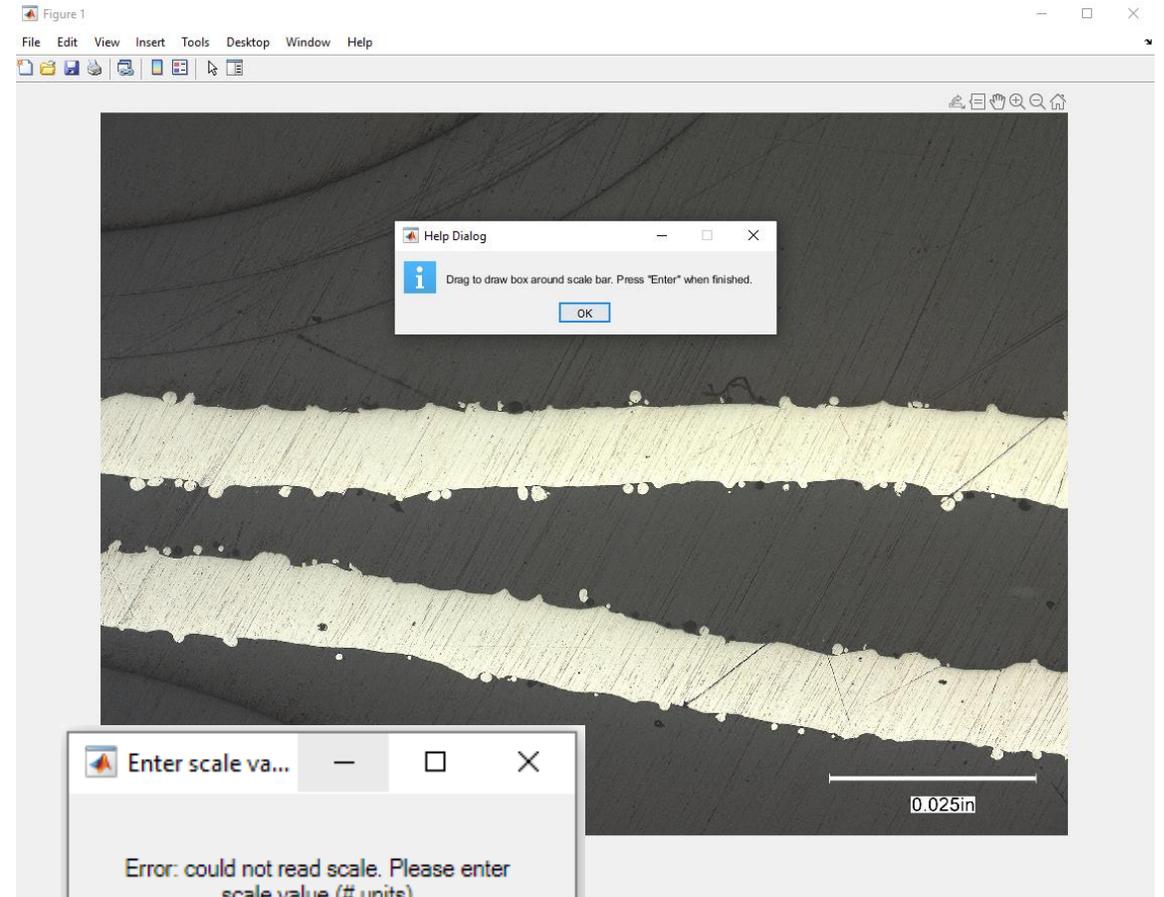
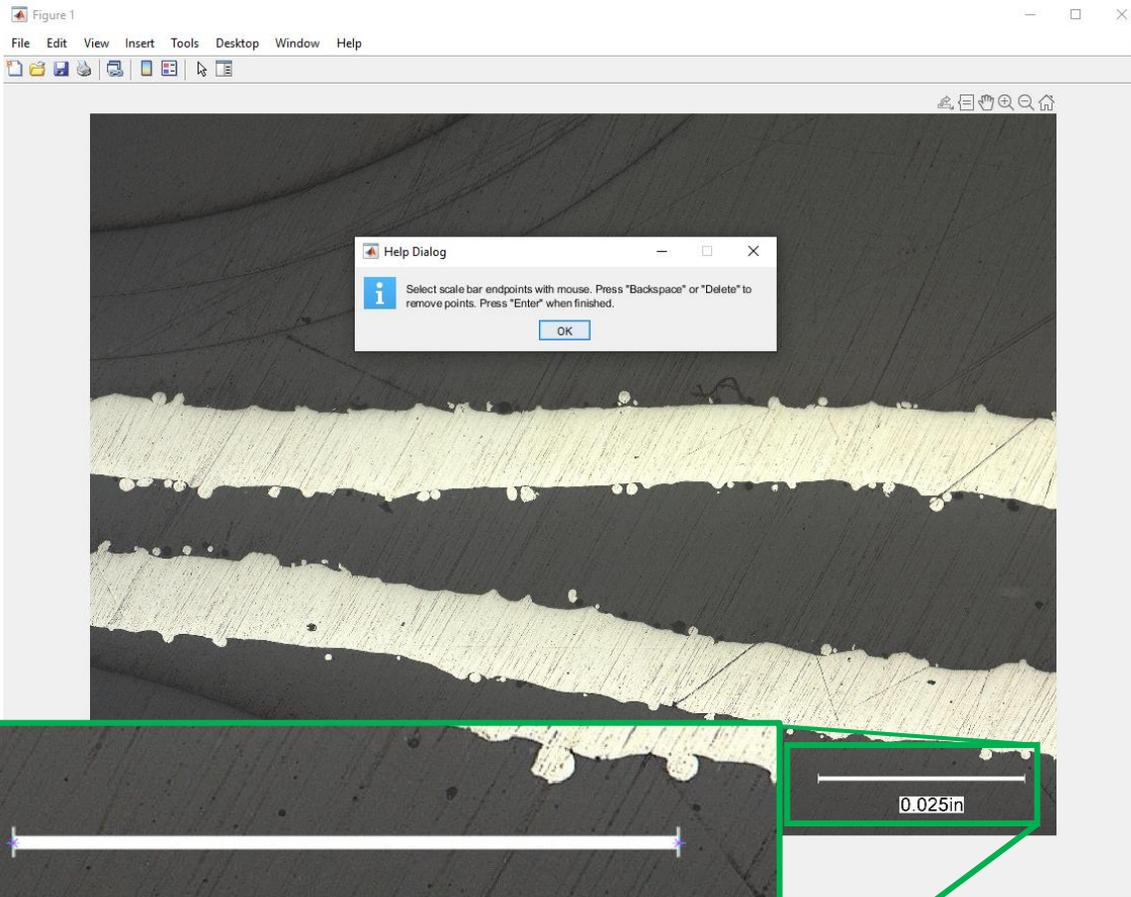


Project #2: Scale Bar Capture

Scale bar disappears during image processing

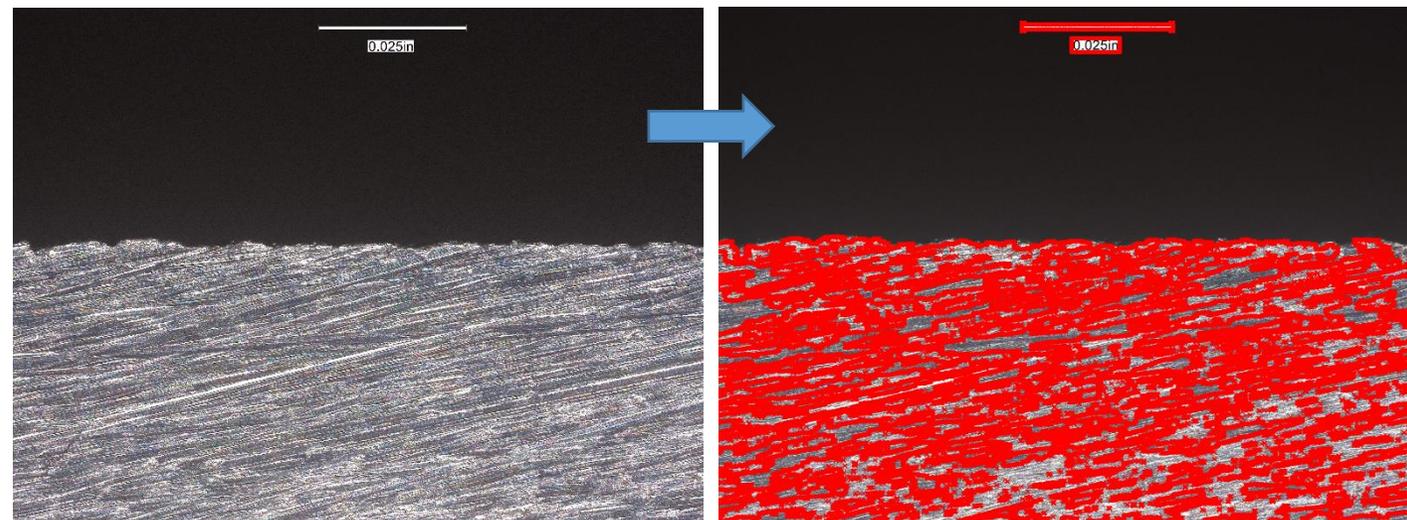
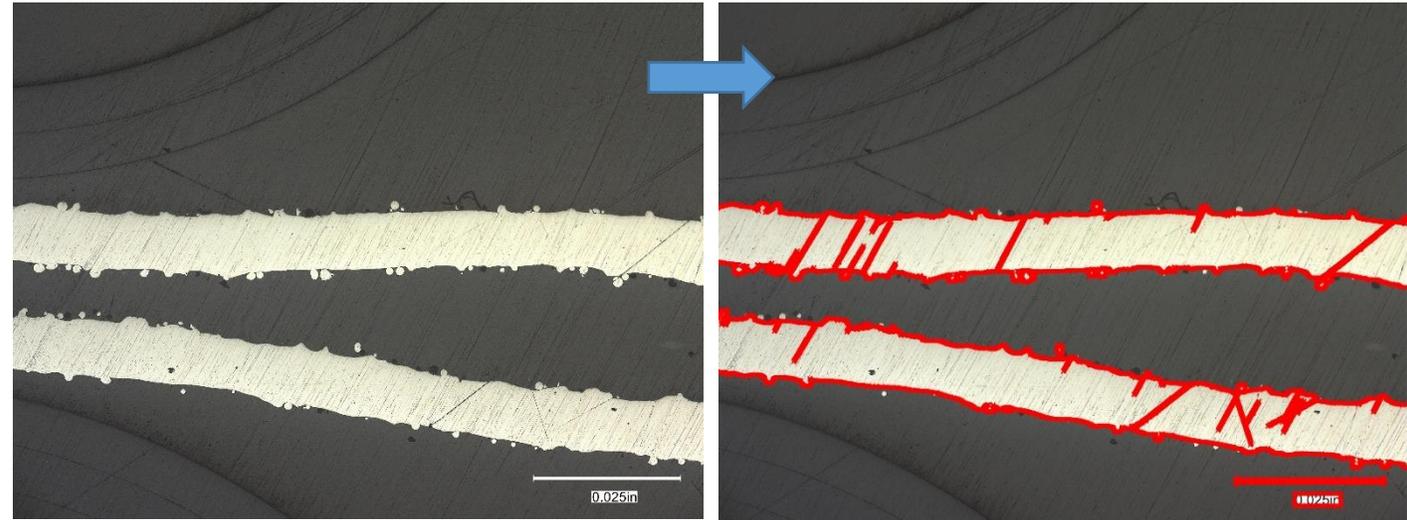


Project #2: Scale Bar Capture



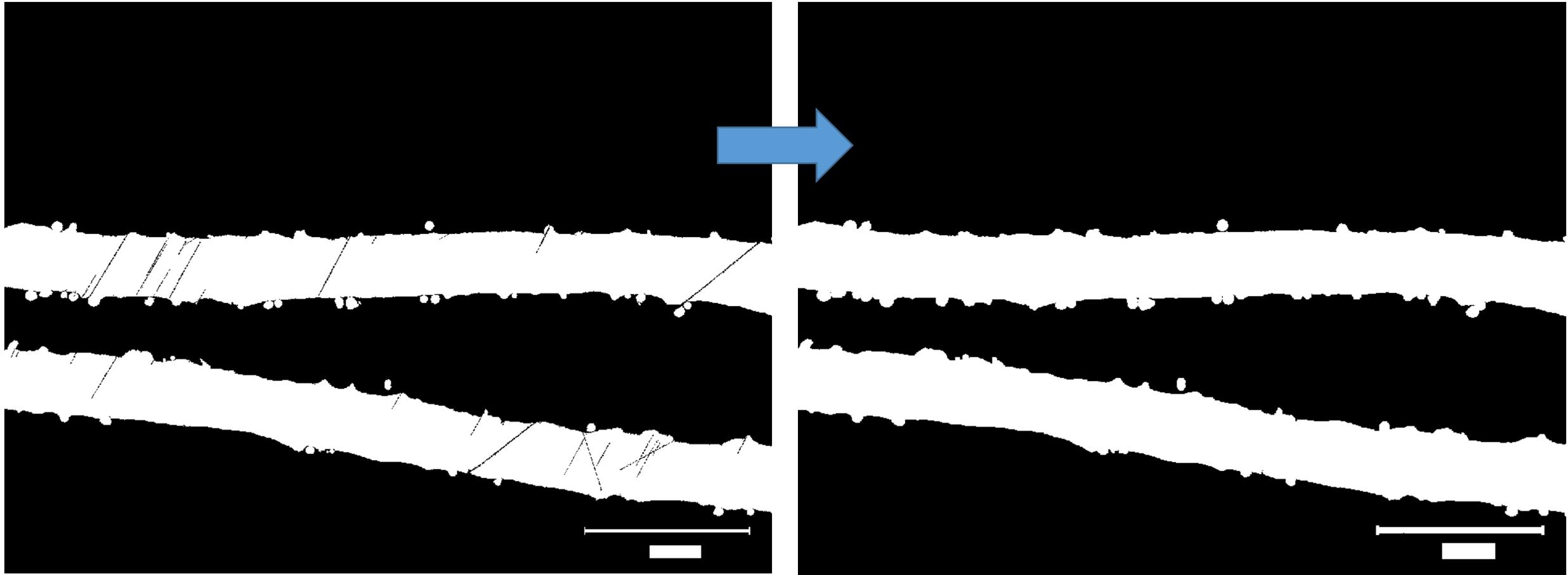
Project #2: Profile Refinement

- As of now, boundary-tracing function relies on generating a binary (BW) image
- Scratches/image artifacts showing up in profile
 - Impacts roughness accuracy
 - Profile shape still captures section edges
- Multicolor images generating incorrect BW profiles
 - Section edges not apparent from traced outline



Project #2: Profile Refinement

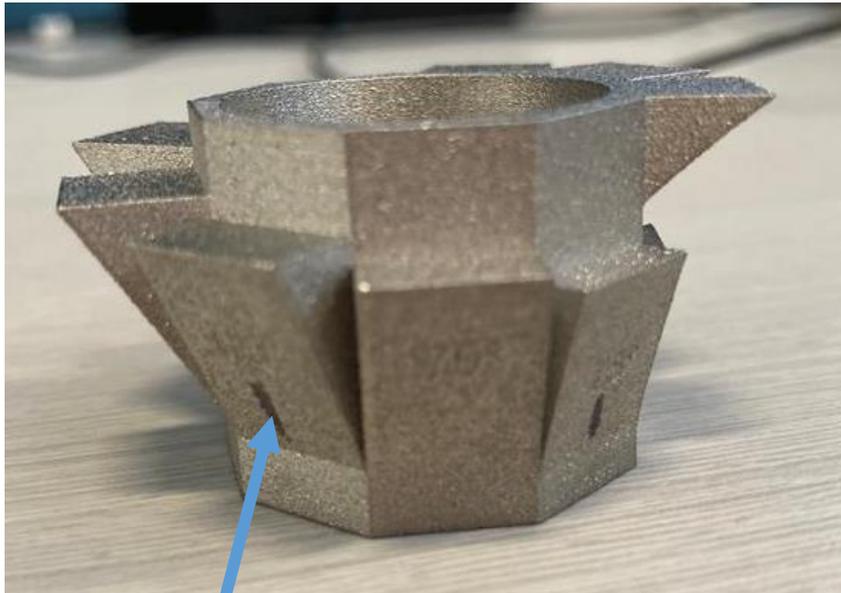
Image erosion to remove artifacts (i.e. scratches)



Project #2: Validation Data

Profilometer Scans

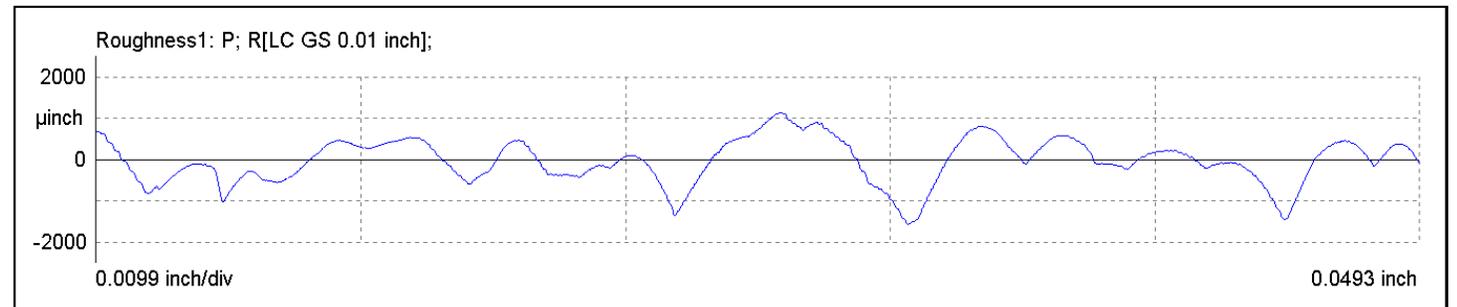
Validation Part



Location of scan (black line) for each plane

Contact Profilometry Data Summary

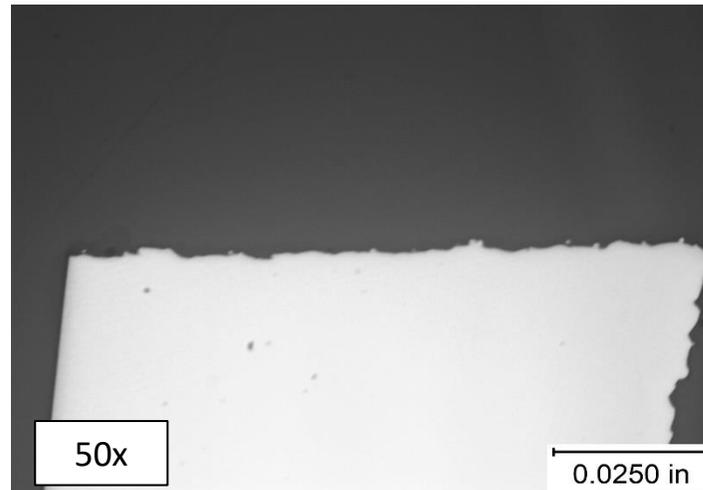
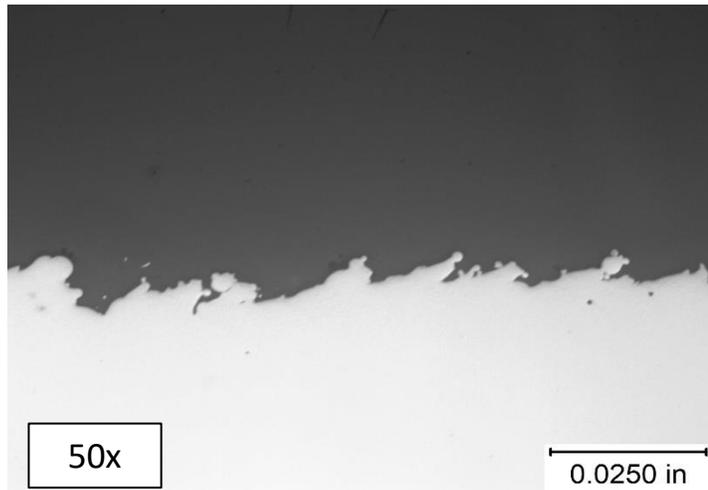
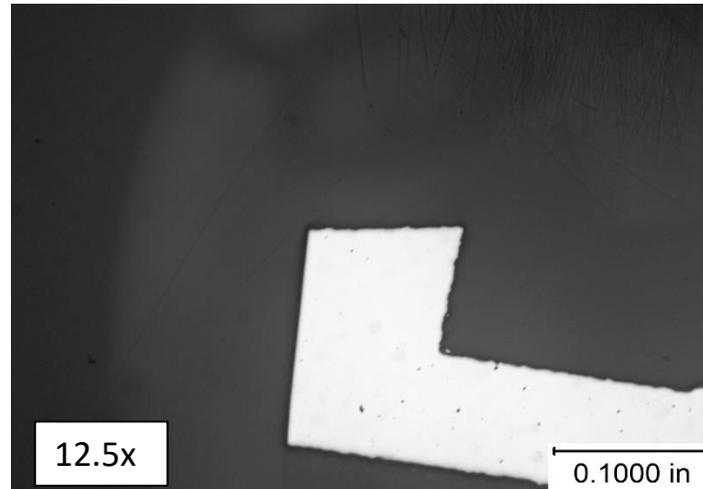
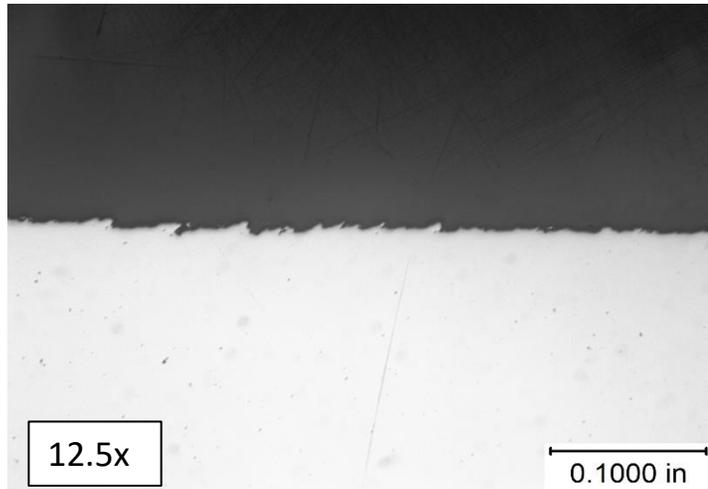
Build Angle (°)	Measurement 1 (μin Ra)	Measurement 2 (μin Ra)	Average (μin Ra)



45-degree Surface Profile

Project #2: Validation Data

Olympus Images



45-degree Surface

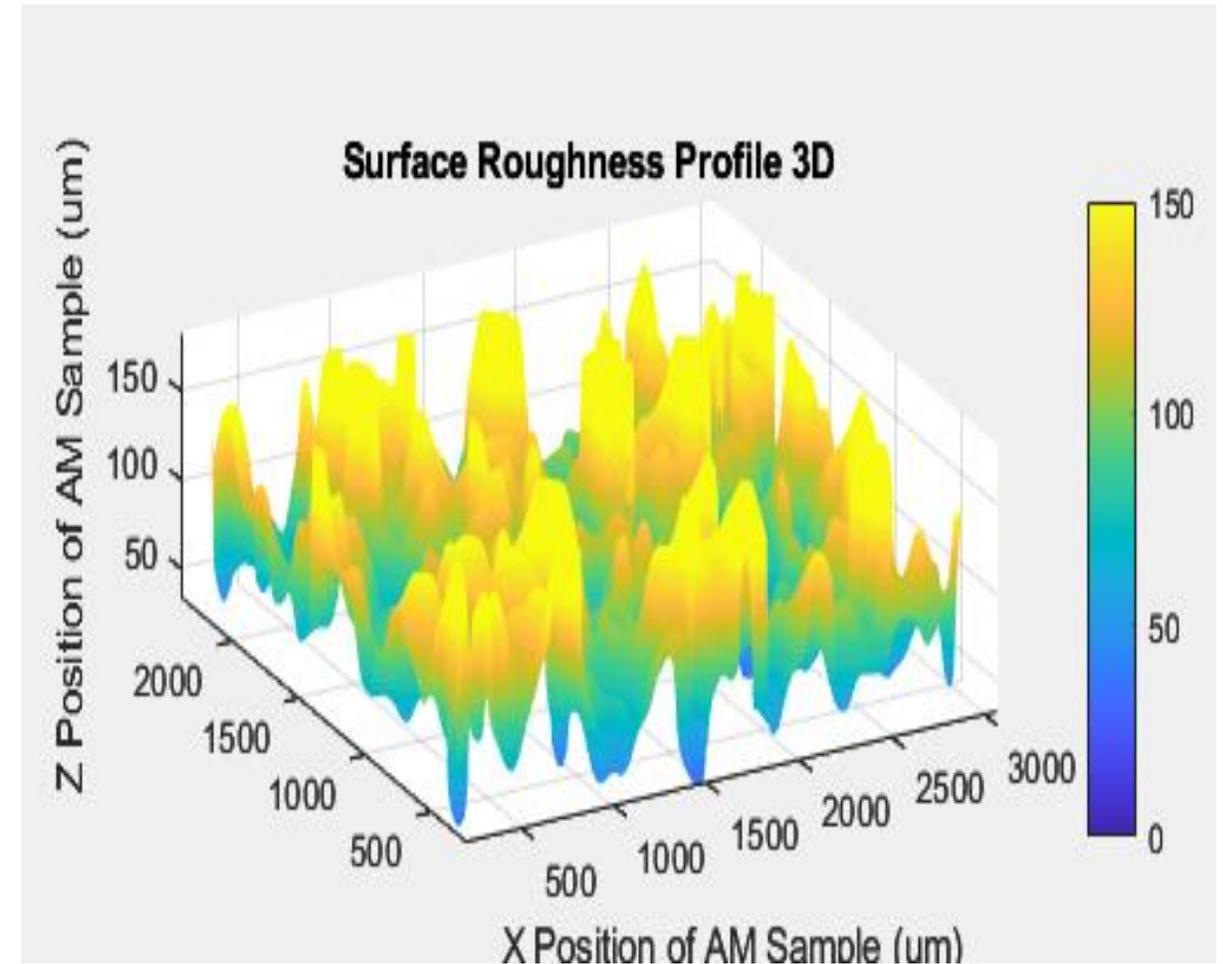
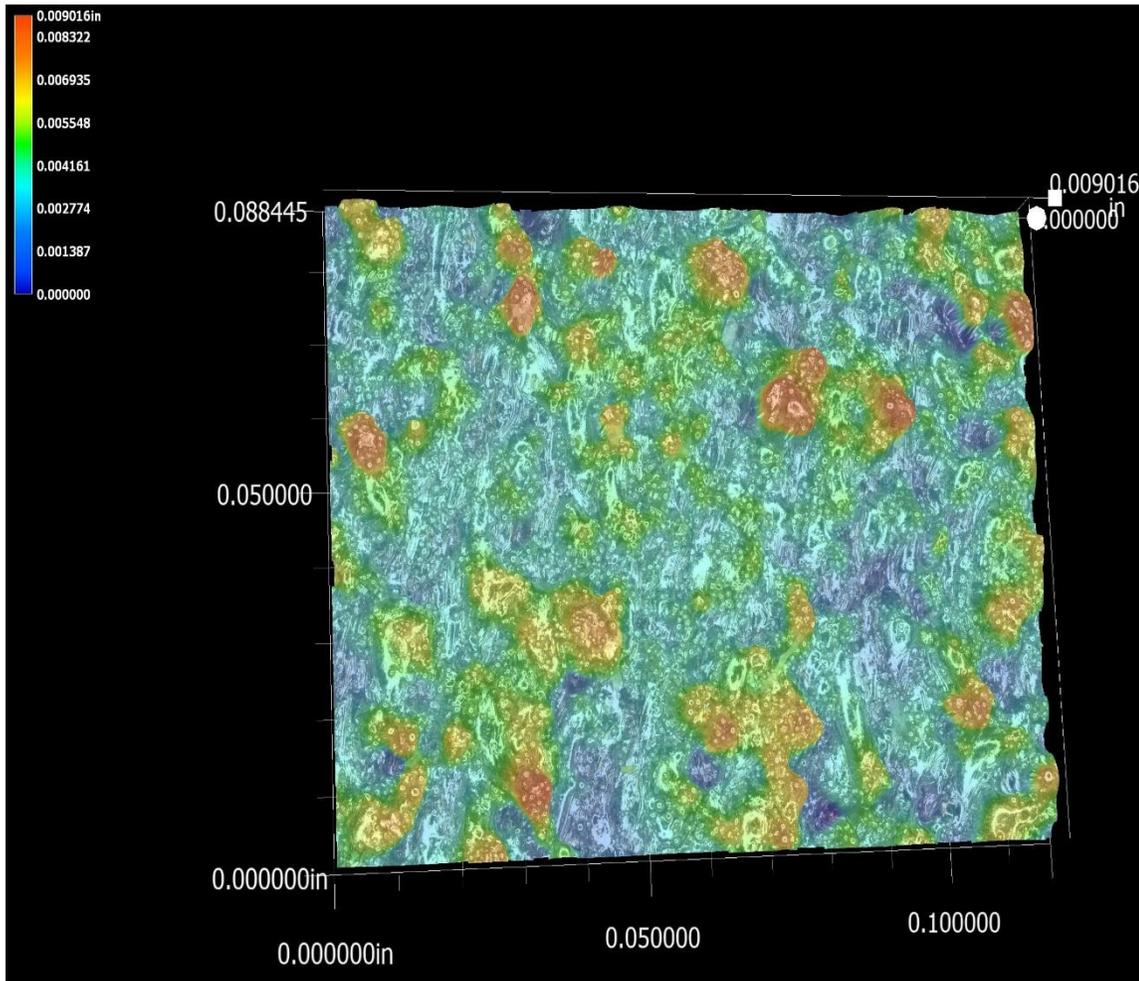
85-degree Surface

Validation Part



Project #2: Validation Data

3D Surface Profile



Q&A

Special Thanks

Brad Hanks
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John Strollo
Megan Waller
Bill Watkins

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Southwest Research
Institute

Tyler Boveington
Daniel Shang